CHAPTER IX

BASIC AERODYNAMICS

In this chapter, I'm going to talk about some basic principles of aerodynamics. It will not be an in-depth discussion —just enough so that when we come to the point of trimming a glider for flight, or analyzing its flight characteristics, you will be able to understand what is going on — at least in broad terms.

Section 1 — The Forces in Flight

A powered airplane moves through the air by means of its motor. It derives its energy from the fuel the motor burns. The powered plane has another source of energy — its height above ground. It took considerable fuel energy to attain the height, and at least a portion of this energy is now available as **potential energy**. That is, if the motor were to stop, the airplane could travel many times its height, by using up this potential energy. If we restart the engine, and fly level again, we are not changing the potential energy, as the height is not changing. The energy in the fuel is now expended to overcome the forces trying to pull it down, and hold it back. The forces trying to hold the airplane back are called **drag**, and are created by the air rubbing against the surface of the airplane, as well as a number of complex factors having to do with the air having to change its direction and velocity, due to the passage of the airplane.

As we know, gravity is trying to pull the airplane back to earth so something must be preventing this. This something is called lift. Lift operates upward to conteract the downward force of gravity. When our airplane is flying level, going neither up nor down, the force of lift exactly equals the force of gravity. Since we do not get something for nothing, the deflection of the air molecules to create lift also generates considerable drag force.

Not having the engine like that of the powered airplane, our glider uses the potential energy it has, by virture of its height, to fly around the sky. Most times, but not all, we try to use this energy up as slowly as possible so we will stay in the air as long as possible. Sometimes, in order to fly faster, we use our available energy faster, in order to get to an area of external energy — a rising current of air — a thermal. But, regardless of whether the glider is rising in a thermal with respect to the ground, it is always **falling** with respect to the surrounding air. It must continually use energy to fly.

Section 2 — How A Wing Lifts

While driving in a car as a kid, I'm sure you have all held your hand out the window, and felt the force of the wind. If you rotated your wrist, so the front of your palm was slightly elevated, you felt an upward force on your arm. This rotation is called **positive angle of attack** which refers to the angle your palm makes with respect to the flow of air. A downward twist would be **negative angle of attack** and would cause your arm to be pushed down. Rotate you palm straight up and down, and your arm was almost broken by the rearward force. This is called **drag.**

A simple flat board with no curvatures can be made to lift, and serve as a wing, but lift will be only marginal, and the drag will be great. So we have learned, through experience, that airfoils add to the performance of wings. If we were to cut through a typical glider wing, the end (or cross-section) would look like Figure 1.

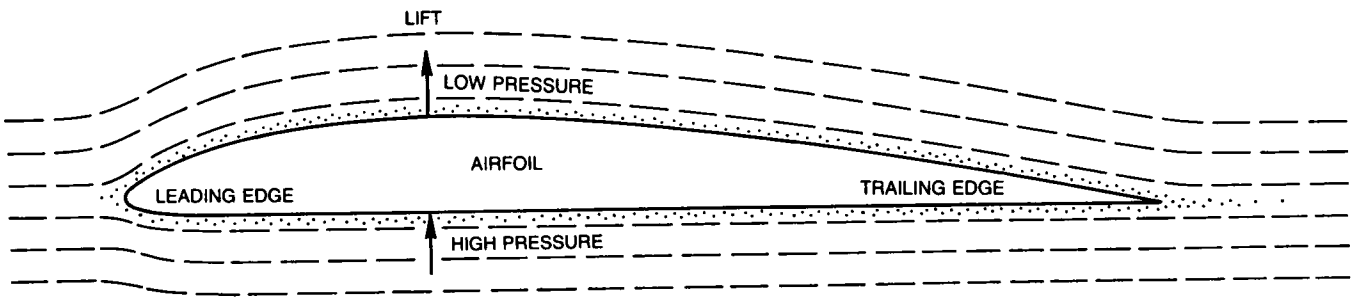


FIGURE 1
AIRFLOW OVER AIRFOIL CAUSES LIFT

This is called an **airfoil**. The leading edge is rounded; the trailing edge is sharp; the upper surface is curved, with the high point from 1/3 to 2/5 of the way back from the leading edge; the bottom surface is flat, or very slightly curved. An airfoil of this type generates about 1/3 of its lift from the lower surface and 2/3 of its lift from the upper surface.

How does it do this? As the airfoil-shaped wing moves forward through the air, the air separates at the leading edge and meets again at the trailing edge. If you will look at the airfoil in the illustration you will notice that the air must travel a greater distance over the top surface of the airfoil than the bottom surface. If it is to arrive at the trailing edge at the same time, it means that the air must travel faster over the top of the airfoil than the bottom. Due to a principle of physics called the Bernoulli Principle, the faster moving air on the top surface causes a lower pressure against the top surface than the slower moving air at the lower surface. As a result of this pressure differential, the wing tends to move from the higher pressure area on the bottom side, toward the lower pressure area on the top side. This upward movement is called **lift**.

As the air molecules move over the airfoil, both on the top surface and the bottom surface, they rub the surface, and are slowed by friction. This frictional force tends to hold back the airfoil in its flight, and is called **drag**. This frictional force occurs in a layer very close to the wing. This layer is called the **boundary layer**. If the air flowing in the boundary layer is flowing smoothly, it is called **laminar flow**. Sometimes the smooth flow of air will separate from the surface, and the boundary layer will fill with turbulent air currents. Sometimes turbulent boundary layers are caused by surface roughness. In any case, a turbulent boundary layer causes more drag than a laminar flow layer. However, for reasons beyond the scope of this discussion, turbulent flow may be desired on model wings, and airfoil geometry, and/or surface roughness, is sometimes deliberately introduced to generate a turbulent condition. A number of other types of drag are generated having to do with how a particular airfoil or wing form disturbes the air through which it is traveling. The way the air leaves the trailing edge of the wing, and rejoins air from the opposite surface, creates a **wake drag**. Air flowing off the wingtips generate swirling air currents called vortexes causing **tip drag**.

The geometry of the airfoil and wing shape has a very complex relationship with the air in which it flies. Changing any of the shapes or dimensions of a wing, or even the speed at which it flies can have a profound effect on the lifting, or drag characteristics of the wing. The designer can, at will, change the performance characteristics. However, the expression "you can't get something for nothing," is especially true in aerodynamic design. An improvement in one area results in degradation in another. The designer, therefore, must reach a compromise between what he wants, and what he doesn't want.

One other problem plagues the model glider designer. Much theoretical and wind tunnel work has been done on wings at higher speeds. Unfortunately, results obtained at higher speeds are not valid at the low speeds of model gliders. A measurement called the **Reynold's Number**, having to do with size and speed of the airfoil comes into play. Increased interest in low speed characteristics of airfoils for energy producing devices, such as windmills, is generating new data.

Section 3 — How Airfoil Lift Can Be Varied

When we stuck our hand out of the car window, we noticed that the faster the car was traveling, the more lift that was generated. Also, as we rotate our wrist, increasing the positive angle of attack, more and more lift is generated. At some point, however, lift seems to be suddenly lost, and our hand is pushed backward with pure drag. Referring to the airfoil shown in the drawing, if it is at a negative angle of attack, with respect to the air flow, negative lift is generated and the airfoil is pushed down. As we rotate the airfoil clockwise, less and less negative lift results. At some point, usually a slightly negative angle, there will be zero lift generated, and the airfoil is pushed neither up nor down. As the airfoil is further rotated, positive lift is generated, and it is pushed upward. Lift continues to increase with further rotation, until it reaches a maximum point. If the airfoil is rotated further, the air flowing over the upper surface acheives complete separation from the surface and swirls and eddies in complete turbulence. At this point, lift is lost from the top surface, and the wing has only that small lift generated by the bottom surface. Drag goes up, and the lift to drag ratio falls dramatically. This point is called the **stall** angle. When a glider wing reaches the stall angle, the nose generally drops, and the ship may fall ten or fifteen feet before it recovers. Some wings stall very gently, others stall violently, to the point where the glider can flip over on its back. Just remember, a wing can stall at any speed, as long as the stall **angle** is exceeded. People make the mistake of believing that planes stall when the speed is too low. The reason for this error is that to the casual observer, it **appears** that slow speed is the fault when a ship stalls. As the plane is slowed up, lift goes down. To compensate for the loss in lift due to speed, the angle of attack of the wing is increased, to generate enough lift to support the airplane. This process is continued, until the wing exceeds the angle where stall occurs, and it does indeed stall.

One type of stall, often seen in model gliders, is called **tip stall**. In a tip stall, the outer end of the wing panel

reaches a stalled condition before the inner panel. The stall usually progresses down the wing, from the tip to the root. This type of stall is very undesirable. It often occurs during launch. The glider veers wildly to one side, and it requires quick, and drastic corrective measures to prevent a crash. Sometimes it occurs during a low-speed turn, and the glider will nearly flip on its back. Proper wing design will prevent this condition by causing the wing to begin a stall at the root, progressing outward to the tip. One method of preventing tipstall is to use **washout** in the end of the wing panel. This means that the wing tip is permanently twisted so that the leading edge is lower than the trailing edge. As the angle of attack of the tip is now always lower than that of the inner wing, the tip will stall last.

Section 4 — Center of Pressure

We talked before about lift being generated by a pressure differential between the top and bottom surfaces of the wing. This pressure differential changes from place to place on the airfoil, and depends on the shape of the airfoil, which affects the velocity of the air at any given spot. The amount of lift generated is generally higher at the front part of the airfoil than at the rear. It is convenient to not think about all these small areas of lift, but pretend they are replaced by one big lifting force, at one spot on the airfoil. This spot is called the **Center of Pressure**. Pulling up at this spot would make the wing behave exactly as it really does with upward pressures all over the wing.

One bothersome point is that, with different angles of attack, this center of pressure changes location because of a changing pressure pattern over the wing surface. As the angle of attack increases, the center of pressure moves forward which tends to further increase the angle of attack, and the wing will rotate. If you take just a wing panel and try to glide it, the panel does not glide, but will turn over and over, all the way to the ground. So, to be useful to us, we must make the wing stable and keep it from rotating.

Section 5 — Wing Stabilization

Flying wing designers have obviously solved the wing instability problem. In a flying wing, the airfoil is so designed that as the angle of attack increases; the center of pressure moves rearward, opposing the increase. This is normally done with an up-curve in the trailing edge. This is called a reflex airfoil. In this solution to instability, one characteristic of the airfoil fights another to keep things in balance. Despite claims to the contrary, flying wings are less efficient than conventional designs and are usually not competitive in model glider competition.

The more conventional way to stabilize the wing is to add another small wing, called a stabilizer, at a distance behind the wing. The stabilizer has another important function — that of changing the angle of attack of the wing. To increase the angle of wing attack, the stabilizer incidence is decreased. This forces the stabilizer down, which increases the angle of the wing. To decrease the angle of the wing, we increase that of the stab, causing it to become a lifting surface which raises the tail and decreases the angle of the wing.

Section 6 — Rudder Action

The rudder of a sailplane performs the same action as it does on a boat. In order to turn the plane, sideward lift is generated by the rudder, usually located over the stabilizer, aft of the wing. This points the nose of the airplane in the desired direction; which is called **yawing**. Unfortunately, this action will not satisfactorily turn an airplane. We need to tilt the plane in the direction of the turn. This prevents the plane from just skidding. This tilting is called **banking**. A plane with just rudder and elevator control has no pilot-controlled way to cause the plane to bank in a turn. We must, therefore, build in some automatic banking method. This is done by means of **dihedral**. Dihedral means that each side of the wing is bent up so that each tip is higher than the root. If we were to hold up a glider having dihedral, looking directly at the nose, and turn it a bit, we find that we see the bottom of the wing nearest us, and the top of the far wing. This means that when we yaw, or turn a glider, the forward wing has a greater angle of attack than the rearward wing. The wing with the greater angle of attack has more lift and, therefore, rises and the glider rolls into a bank, which is what is desired.

Another method of banking is by the use of ailerons. These are a section of the trailing edge, hinged at the front edge as shown in Figure 2.

The ailerons are normally deflected in opposition; that is, when the right hand aileron is raised, the left hand aileron is lowered. Air pressure on the lowered aileron causes that wing to rise. Air pressure on the raised aileron causes that wing to drop, causing a rolling action which banks the airplane. This does not turn the airplane. The rudder must be also deflected in the direction of the lowered wing to cause a yawing, or turning motion in the direction of the lowered wing. Many times, in gliders which use ailerons, the rudder is coupled to the ailerons so that one control action moves both in a coordinated fashion. This automatically produces a smooth, coordinated turn, requiring only one control lever.

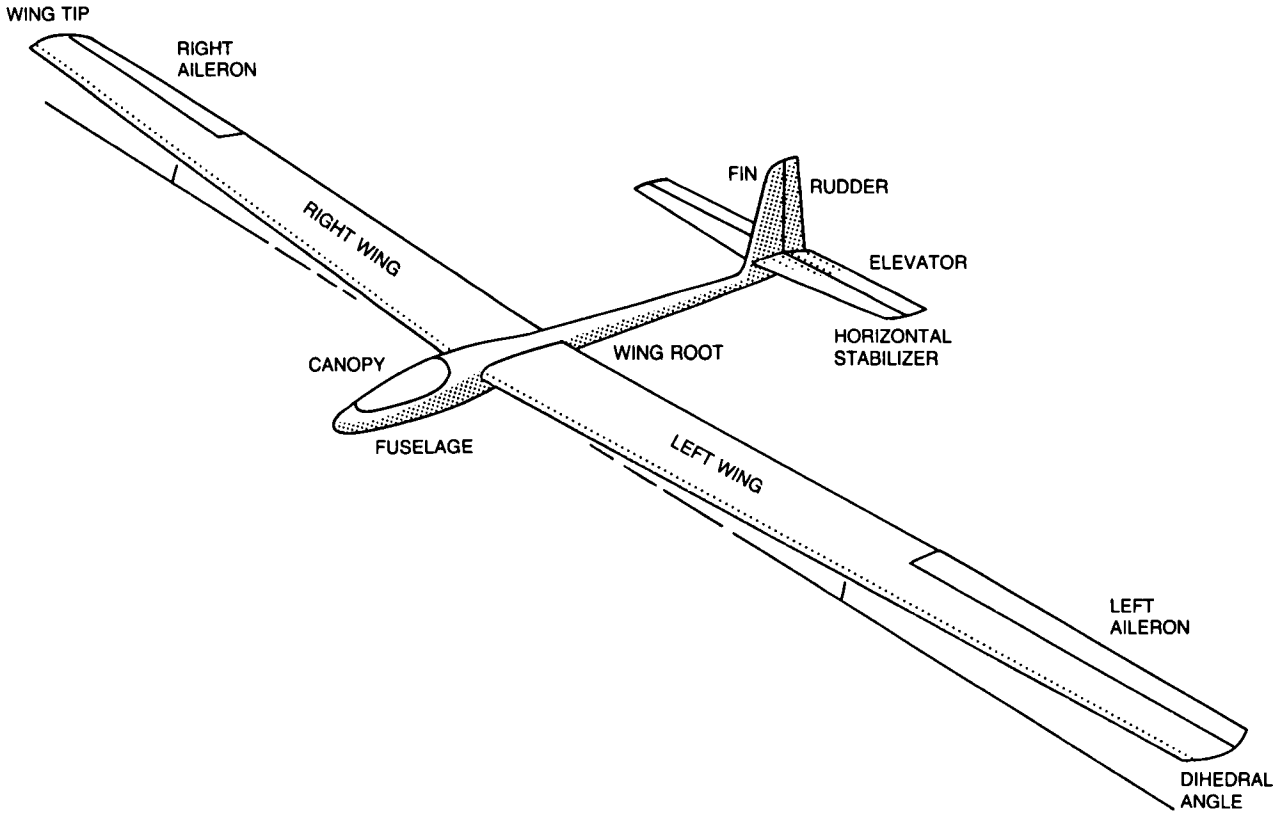


FIGURE 2
PARTS OF A SAILPLANE

Section 7 — Maximum Glide Angle versus Minimum Sink Rate of Sailplanes

We talked before about how the lift of an airfoil varied when we changed the angle of attack. As the angle is increased relative to the flow of air, the amount of lift generated increases. The drag, created by the wing, also increases. At that point of negative attack (zero incidence), where the wing is generating no lift at all, the glider will dive straight into the ground. As we increase the angle of attack, the ship will glide farther and farther. The glide angle of the glider is represented by the ratio of Lift/Drag, or L/D. If the lift is increasing faster than the drag, the glide angle of the ship becomes flatter and flatter, and it will glide farther and farther. This is exactly what happens: as the nose of the glider is raised, the angle of attack increases and the ratio of L/D increases. At one particular angle, however, the drag begins to increase faster than the lift, and the ratio of L/D and, therefore, the glide angle reaches a maximum. This is an important concept to remember. Another point is: from the zero lift setting at which the plane dove into the ground, to the setting of flattest glide angle, the glider was flying slower and slower.

As we continue to increase the angle of attack, the ship continues to slow down. However, as the L/D ratio is now decreasing instead of increasing, the glide angle begins to worsen. As the angle of attack continues to increase, a point is reached where the airfoil airflow becomes suddenly turbulent and drag increases rapidly, with lift dropping dramatically. This is the stall point we talked about earlier. The nose of the glider will normally fall, and it will lose altitude rapidly.

At an attack angle between the maximum L/D point and stall, is another angle of attack of interest; it is the point of minimum sink. At this angle, the ship will not travel as far or go as fast, as at the maximum L/D point, but it will stay in the air longer. This is the point of minimum energy dissipation, and is a useful setting for climbing in thermals or staying up in light slope lift.

Section 8 — Flaps

On some gliders a long strip of the trailing edge of the wing is hinged, permitting it to be raised a few degrees and lowered as much as 90 degrees.

The basic purpose of flaps is to permit an in-flight modification of the airfoil. If the flaps are raised slightly above the zero position, the speed of the glider will increase and it will penetrate into wind better. As flaps are lowered, the airfoil bottom becomes **undercambered**, or concave, and lift will increase, which is useful when in thermals or in take-off. When lowered all the way, flaps become an air brake as they create a tremendous amount of drag. This is useful to slow the ship to a safe airspeed when diving out of a thermal, or to slow the speed for landing.

Section 9 — Spoilers

On some gliders you will notice a fence that pops up out of the top (and sometimes the bottom also) of the wing as shown in Figure 3.

These are called spoilers. As they are deployed, they do two things: they **spoil** the lift in that area of the wing but, even more important, they add a great deal of drag to the glider. This combination destroys the L/D ratio and changes the glide ratio from 10-12:1 to about 3:1. Spoilers are used to control the descent rate when landing, so that the ship can be more easily landed on a particular spot.

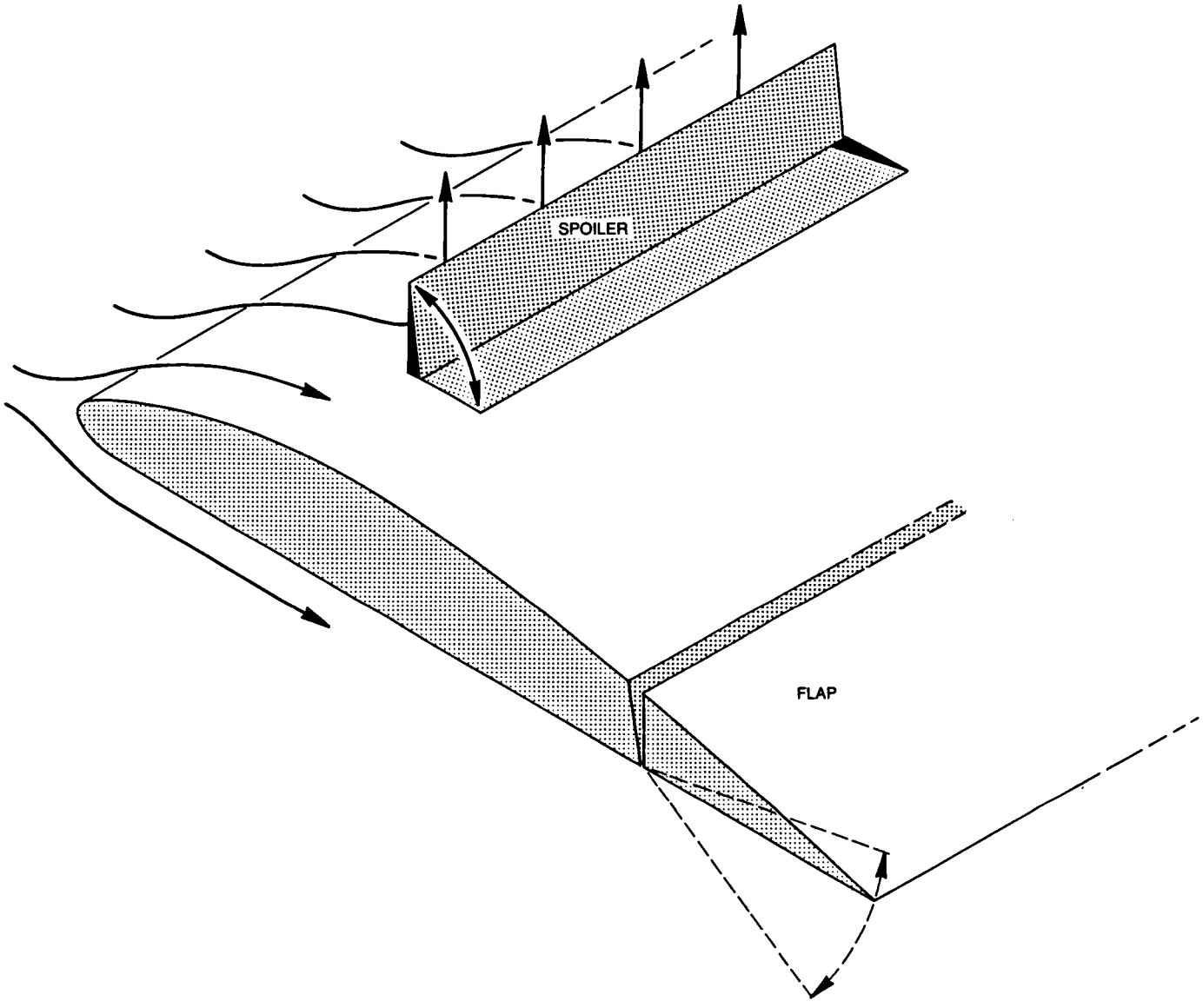


FIGURE 3
FLAPS AND SPOILER CONFIGURATION

Section 10 — Trimming An R/C Sailplane

This section is included in this chapter so you can think about it while the terms and concepts are fresh in your mind. You won't want to put them into practice until you have become a little experienced at flying — at least experienced enough to detect changes in flying characteristics. There are really only three things you can adjust: lateral balance, decalage (the angle between the wing and the stabilizer) and Center of Gravity.

First of all, lateral balance is easy. This just means you must make sure that one wing is not heavier than the other. You will, of course, check this every time you build a new airplane. You should also re-check it each time you make any repair to either wing. Before covering the wings, suspend the assembled ship by the nose and tail. There should not be a tendency to drop one wing. If there is, tape a weight to the light tip. Add or remove weight until balance is achieved. Now, epoxy the weight in position on the tip spar (in front of the spar to help statically balance it). If the wing is already covered, drill a hole in the wing tip or remove the covering from the lower panel to add weight. Do not skip this procedure or you may have a glider that needs a mysterious bit of rudder trim in order to fly straight.

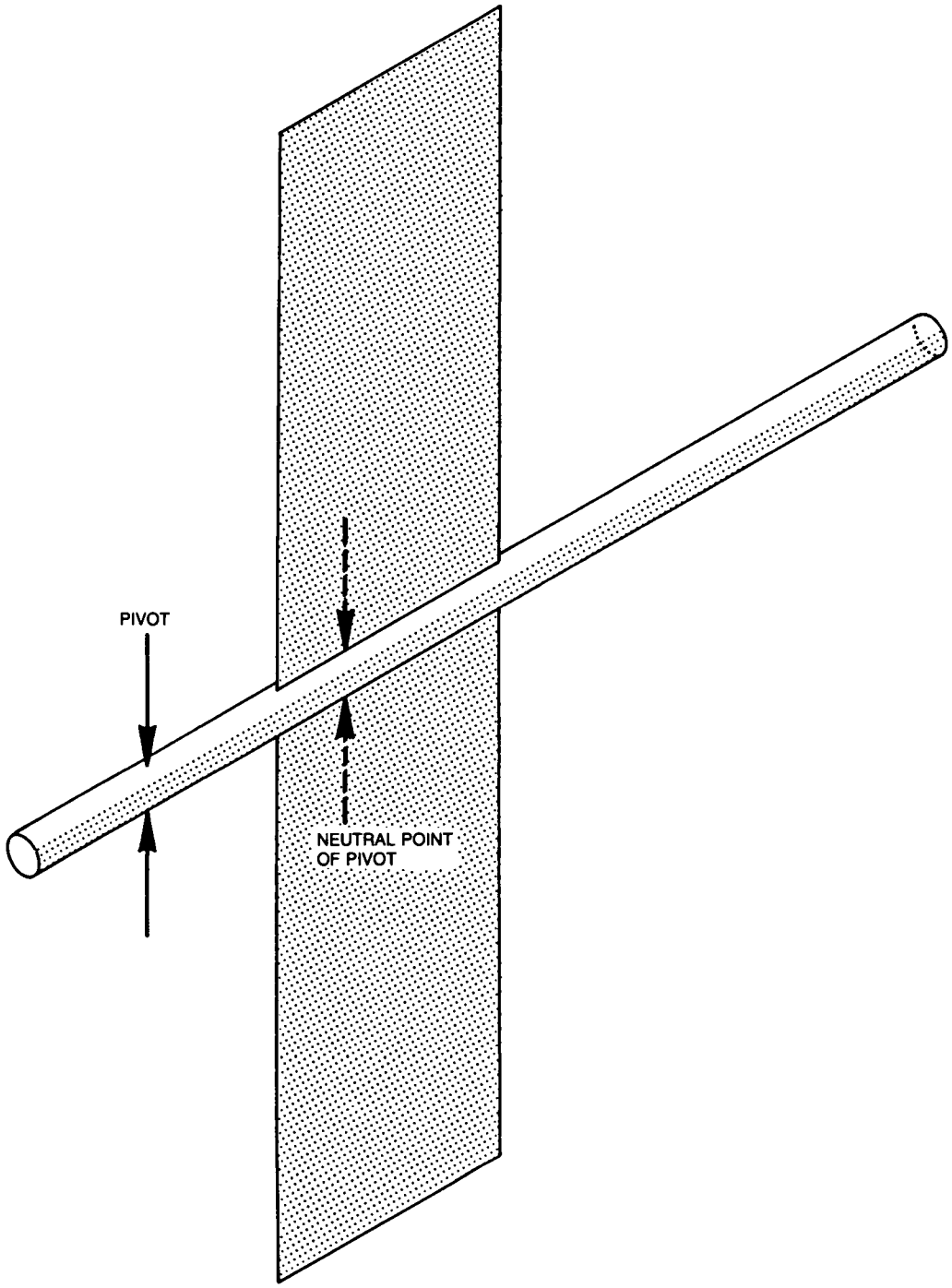


FIGURE 4
WEATHERVANE ILLUSTRATES NEUTRAL POINT

Before adjusting the Center of Gravity, check the decalage. This is the incidence angle of the wing with respect to the stabilizer. The correct angle can be obtained from the side view of the plans. Most designs try to establish this angle with some foolproof construction method. I have found, however, that it is possible to circumnavigate all these methods, and do it wrong. If you find the angle is not correct, you may have to shim either the stabilizer or wing or modify the fuselage or stabilizer platform support by sanding. If the stabilizer design is of the flying stab type (i.e., the whole stabilizer rotates instead of having an elevator section at the rear), there is no adjustment necessary. Adjustment is with the transmitter trim lever. You should, however, in this case, mark the center position on the fin so you can easily make initial adjustment.

The exact position of the Center of Gravity is **somewhat** a matter of preference. The C.G. position is commonly measured in percentage of wing chord. Its effect, however, is related to its position ahead or behind a thing called the **Neutral Point**. As we remember, gravity is the force that holds us on the ground and pulls our gliders out of the air. Even though gravity is pulling on every piece in our glider, we can, to simplify things, replace all these forces pulling all over the glider, by just one big, force pulling at the centroid of all these little forces. Like the equator, C.G. really doesn't exist. C.G. is the exact spot where, if the whole world grabbed onto our glider, it would behave exactly like it does with all those little forces acting all over it.

C.G. is rather like the pivot point of a weathervane. As we add nose weight to our glider, it would be like moving the pivot point of the weathervane forward. As we remove nose weight from our glider, it would be like moving the pivot point back. As shown in Figure 4, if the pivot point is ahead of the vane, the weathervane will point into the wind. As we move the pivot point back, a point is reached where the weathervane doesn't know which way to point, and the system goes unstable. This point of instability is called the **Neutral Point.**

On aircraft, the distance between the C.G. and the Neutral Point is called the Static Margin, and is measured in wing chords. In our glider, as we move the C.G. rearward, we reach a point of weathervane instability and our system starts going bananas. The result is the familiar "nose light" glide which is not the result of a stall, but the system instability. This switchback motion is called Phugoid motion, and generally increases in violence as drag goes down. In a clean model, Phugoid may set the maximum glide angle that can be obtained. This somewhat over-simplified explanation was presented to a DCRC Symposium of R/C models in 1958 by Norman K. Walker and seems quite lucid.

Now that we have defined a few things, let's let Ken Banks of the Torrey Pines Gulls Club tell us about the effects of C.G. movement.

For slope aerobatic flying I prefer a C.G. only slightly forward of the Neutral Point. If you dive such an airplane, it will stay in the dive until you give up-elevator to pull out. Left to itself, it would require perhaps 700-1000 feet to pull out. Such a C.G. makes it easier to fly precise maneuvers as you are not obliged to make additional control inputs to compensate for the aircraft's attempts to pull itself into level flight. For sport flying and thermal flying, a slightly more forward C.G. is desirable as you do not want to have to correct for the effect of every gust. However, an excessively forward C.G. has undesirable effects. First, the aircraft recovers very quickly from any pertubation and may overshoot, and either stall, or make repeated short dips and climbs. Secondly, if the C.G. is far forward, considerable down-force will have to be exerted by the stab. The stab must, in other words, act as a wing flying at a negative angle of attack, lifting downward. The generation of negative lift subtracts from the wing lift to reduce the total lift generated by the airplane, and also may result in additional profile drag from the stab, both of which cause a reduction in performance of the airplane. The drag discussed here is called ***trim drag****. Too far aft a C.G. may also be ineffective, as the stab is forced to lift. This does not sound bad at first, but the stab makes a poor wing because of low Reynold's Number, and/or aspect ratio. As the stab angle is increased, the penalty in drag for this lift eventually becomes worse than the benefit from the lift.*

You can get an idea where your C.G. is, in relation to the Neutral Point, by making a dive test. Trim the aircraft in level flight. Now, push over into about a forty-five degree dive. Stabilize the aircraft in the dive (usually this means backing off the down-elevator from the amount used in the initial pitch-over). The idea is to establish a steady straight dive, for ten feet or so. Then freeze the stick position and observe the aircraft trajectory. If the dive steepens of its own accord (tucks), the C.G. is behind the Neutral Point. If it continues on a straight line, the C.G. is just on the Neutral Point. If the aircraft pulls out by itself, the C.G. is forward of the Neutral Point, and the faster the pull-out, the more forward. Be careful, especially with aircraft wings, with undercambered airfoils. They often have an uneven center of pressure movement with angle of attack. For a given C.G., they may be stable at high angles of attack and unstable at low angles. In other words, at low dive speeds they will pull themselves out, but if you hold the dive to high speeds (low angles of attack), they may tuck.

Ken also warns us to start this whole thing high enough so as not to run into the ground, and take it easy on pull-out so as not to rip the wings off. So, to review what Ken said: If we start with the decalage and C.G. position

shown on the plans, and start adding nose weight, the sailplane will become more and more stable. The elevator will become less and less sensitive. As we continue to add weight, flying becomes tutti-fruitti. The ship becomes inclined to stall around the sky, and the glide worsens. Of course, as we added nose weight, we had to add compensating up-trim. This is why our nose heavy ship will recover from a dive very quickly. The extra up-elevator serves to pull the aircraft out more rapidly after it is put into a dive. If we go the other way and start to remove weight, we find the elevator becoming more and more sensitive. You will eventually start to notice that the plane is harder to control, and will tend to stay in a dive until deliberately pulled out. As we continue to remove weight, the ship will again go tutti-fruitti, and you will have to fight to keep it straight and level. Again, as we removed nose weight we had to add down-trim to the elevator to hold level flight.

In moving the C.G. fore and aft from the nominal position we find, in most gliders, a fairly broad region of perhaps one half to three-quarters of an inch where the ship is stable and seems to fly well. It is within this region that personal preference comes into play. If you are a new flier and want a ship that will sort itself out of trouble without too much help, lean toward the forward end of the range. If you want an efficient machine, it may help to adjust the C.G. as far aft as you can stand comfortably. Ken Banks gives us some advice when moving the C.G. rearward.

You will find another effect as the C.G. is changed. The closer the C.G. is to the Neutral Point (the further aft), the less elevator movement is required for a given response. This leads to a common error when trimming an aircraft. As the C.G. is moved back, the airplane seems to become too "unstable" in pitch, as it is hard to fly smoothly. The problem may ***really*** *be that there is too much elevator travel, and you will find the airplane easier to fly if you simply move the pushrod out on the elevator horn.*

Now that we understand a little better how C.G. affects the way our glider flies, it's time to talk about the effect of elevator trim on flight performance. There are two trim positions in sailplanes that is of high interest to the pilot. The first produces the flattest glide angle. The second produces the minimum sinking rate. The first is called a maximum L/D glide, and is attained when the angle of attack of the wing is such that the ratio of lift to drag is at maximum. The minimum-sink glide is attained when the airplane is flying very slowly — near to stall. It is the minimum-sink glide that will give the lowest possible descent rate under given conditions. Although you might think that you always want to have your sailplane adjusted to come down the slowest, this is not the case. When you are flying in rising air, such as a thermal, you want your sailplane adjusted to sink the slowest. It will, therefore, go up the fastest. If, however, your plane is in sinking air, you don't want to sit there and sink the slowest — you want to get the heck out of there in the most efficient manner — at maximum L/D.

Writing in the "South Bay Soaring Society News" of November 1979, Ian Turner describes these two conditions very clearly.

Having found a comfortable C.G. position, how can we use the trim controls to the best advantage? Let's just run through the observable effects as we go from very under elevated to the stall point. To begin with, when pushing the trim (or stick) hard forward, the model flies fast and comes down very fast! The wing is made to operate at a very low angle of attack and its drag is lowest. Unfortunately, so is the lift, with the resulting lift over drag ratio being poor.

As the trim is moved back, the plane slows down and its angle of descent reduces. At some point the glide reaches its flattest. The model is still flying quite fast and is not near a stalled condition. This point is the so-called best lift to drag ratio. Interestingly, it is not the point of minimum sink because, although the glide angle is the flattest, the model is flying quite fast down the glide slope. However, it is the point of maximum distance coverage and is, therefore, the trim to use when trying for distance or moving between thermals. As the trim is moved back further, the flying speed reduces more and the glide angle increases (becomes steeper). Just before the stall, the wing is at its highest angle of attack, and it can be shown that the plane is in a condition of minimum energy dissipation and, hence, minimum sink . . . One of the confusing things about this condition is that the glide angle may appear (it is) much worse than the optimum and this can give the illusion of high sink. If you have fallen into this pitfall, I suggest you try timed flights from two launches (on a day without too much thermal activity), one trimmed at best glide angle and one just off the stall. The difference in time may be as high as 25% better for the near stalled condition!

At this point, I'm sure some of you are saying to yourselves, "What, no mention of Reynolds Numbers?" Well, as usual, Reynolds Number effects can completely upset the above statements, so I will make some remarks. Since the flying speed can be greatly different between minimum sink and best glide ratio, it is possible for a very clean model (such as the Aquila Grande) to be operating sufficiently fast at best glide angle that the performance of the airfoil is improved significantly compared to that at minimum sink because of operating at a higher Reynolds Number. In this case the sink rate may be little different between the two cases.

So, there you have Mr. Turner's thoughts. So what do we do about all this interesting information? It would be convenient to have the transmitter elevator trim-tab trim to minimum sink in full up-trim position and to maximum

glide in another known position, say, in neutral (assuming your pushrods don't change length with temperature). Making measurements to determine these two positions is not easy.

Blaine Rawdon, writing in the August, 1979 issue of "Model Aviation," the Official Publication of the Academy of Model Aeronautics, describes a measurement program conducted by the Research and Development Committee of the San Fernando Valley Silent Flyers Club. The data collected enabled this group to determine minimum-sink and maximum-glide speeds of several sailplanes and was done about as well as could be by a club group. It still required six people and two inclinometers of modest accuracy. The tests were run at dawn. Now I can, by using several six-packs as bait, assemble six people. I have sufficient motor skills to assemble the inclinometers. The thing that puts me right off is this dawn business.

Don Edberg of San Diego, has used a measurement technique which, while yielding only minimum-sink trim, can be done by one, or at most two, people. Don uses a short hi-start of perhaps two hundred foot length. He tethers the parachute back to a spot somewhat in front of the launch position, using a hundred feet or so of light string or monofilament line. This tether will provide a constant-altitude release point. The plane is then launched and flown in wide circles without touching elevator, using the rudder trim control only. Flights are made at several elevator trim positions from near stall to fast flight. Each flight is timed. Several flights are made at each setting and the averaged time is used. If the sailplane has a flying stabilizer, each setting should be marked on a piece of masking tape stuck to the fin. If the sailplane has an elevator, the angular deflection should be measured. You will find that one trim setting gives longer average flight times than any other. The transmitter full up-trim position can now be set to this trim position. I forgot to tell you that these measurements must also be made in dead air, very early in the morning (again at dawn). A rough measure of maximum L/D might also be made by finding the trim setting that gives the most distance on an out and back course, or around a constant radius course around the pilot.

Now, if you are lazy like me and believe that only roosters should get up at dawn (us chickens like to stay in bed), you will end up estimating the whole thing. Knowing that the minimum-sink angle of attack is just below stall, set the full up-trim on your transmitter to this setting. This can be done by flying across the field in front of you and pulling back the elevator trim until the sailplane begins to mush; now push the trim lever forward a bit until the plane is flying slowly but in a stable manner. Land and mark this stabilizer or elevator position. Adjust the stabilizer to this position with full transmitter up-trim. Now, when in a thermal, it is easy to find the trim where **most** sailplanes will thermal best.

Finding the angle of attack for best glide angle is tougher. You just have to fly the plane back and forth in front of you and vary the trim until your best guess is that the glide is most flat. On some sailplanes you can "see" the right setting. In his description of flying the "Bird of Time," sailplane designer Dave Thornburg says:

To find that magic setting, you need flat morning air, preferably calm. I can't tell you just where the setting is, but I guarantee you'll know it when you find it: the plane will speed up a little and "go on step" and the L/D will appear to double.

I can vouch for this statement — I've seen it happen.

When you find what you think is the best setting, mark your trim lever on the transmitter. It is convenient if this position is at neutral, then you can find it without looking. This position will be the one to use when you are cruising around the sky looking for thermals — or trying to get back home from too far out. Of course, these settings are only good if your pushrods don't change length with temperature. This means balsa or metal pushrods — but that's a whole other subject.

Section 11 — Adding Weight To A Sailplane To Improve Its Performance

This just doesn't sound right, does it? One specification of sailplanes (and also other types of planes) is called wing loading. For models (in the United States), it is commonly given in ounces per square foot. It is found by dividing the gross weight of the glider in ounces, by the wing area in square feet. For R/C sailplanes it runs from about 5½ for very light floater types to as much as 24 for a slope speed job.

Why add weight? To make it go faster. When wing loading is increased, and the angle of attack of the wing is held constant, the plane must increase its speed to generate enough additional lift to support the added weight. Within a wide range of wing loadings, only the speed varies. The glide angle remains the same. The sailplane will glide just as far — it just gets there faster. The speed will increase by the square root of the increase in wing loading. If you were to double the wing loading, the speed would increase to the square root of 2 or 1.41, to 1.41% of the unloaded speed.

Aside from making speed runs, the time added weight is desired, during windy weather, both for slope and thermal flying. In order to cover ground, it is necessary to be able to penetrate the wind. Hence, the requirement for greater speed. It is not just for contest flying that this requirement exists. Many sport fliers lose much of the ability to enjoy windy weather flying because they do not know how much performance can be improved with increased wing loadings. It also helps to stabilize the plane during windy landings. The weight should be added either on the Center

of Gravity, or distributed either side, so that the balance is not changed. It must be securely fastened to some rigid structure, so as not to move during flight or landing. It doesn't enhance the sailplane flight characteristics to have a half-pound weight slide two inches to the rear upon launch. This same half-pound of lead makes an excellent bulkhead remover, when it flies around during landings.

So, these are a few aerodynamic tidbits for you to chew on. You probably didn't understand all the points, it's a big mouthful to chew early in the game. After you get a bit of flying under your belt, you may want to come back and re-read this chapter. With a bit of flight time, some of the points will be more clear.

So, on to the fun of getting your Oly 650 in the air.

CHAPTER X

LAUNCHING EQUIPMENT

There are many ways to coax a sailplane into the air. One way is with a hand tow. A small ring is tied to about 400' of monofilament fishing line. The ring is hooked to the tow hook and a runner to the other. With no wind, the runner needs good legs to get the sailplane up to altitude. With a bit of wind, it isn't so bad. The launch takes a bit of coordination; you can't throw the sailplane or it will become unhooked. This method is much more popular in Europe than in the United States. Another method is to tow the sailplane up using a powered model. This requires a reasonably large and powerful powered model, preferably a high wing design. Line connection should be made to the top of the wing at about the spar line. The line is connected to the nose of the glider. It is preferable if both ends of the line can be disconnected by radio. In this way, either pilot can terminate the tow. At any rate, the sailplane end needs controlled disconnect. Take-off is critical, and the sailplane must take-off first and stay slightly above the powered tow plane. An electric, or a fuel powered model airplane engine can, of course, be attached to the sailplane for launch power. These are described in another section of this book.

Section 1 — The Hi-Start

By far the most popular launching method in the United States, aside from tossing the plane off a slope, is the hi-start launch. This is essentially a giant slingshot which propels the sailplane into the air by means of a long length of elastic tubing. The hi-start consists of about 100' of elastic surgical tubing with 3/16'' inside diameter and 1/16'' wall thickness; 400' of 30 pound test monofilament fishing line; a parachute; a stake; and some fishing swivels. The parachute provides drag to release the line from the sailplane.

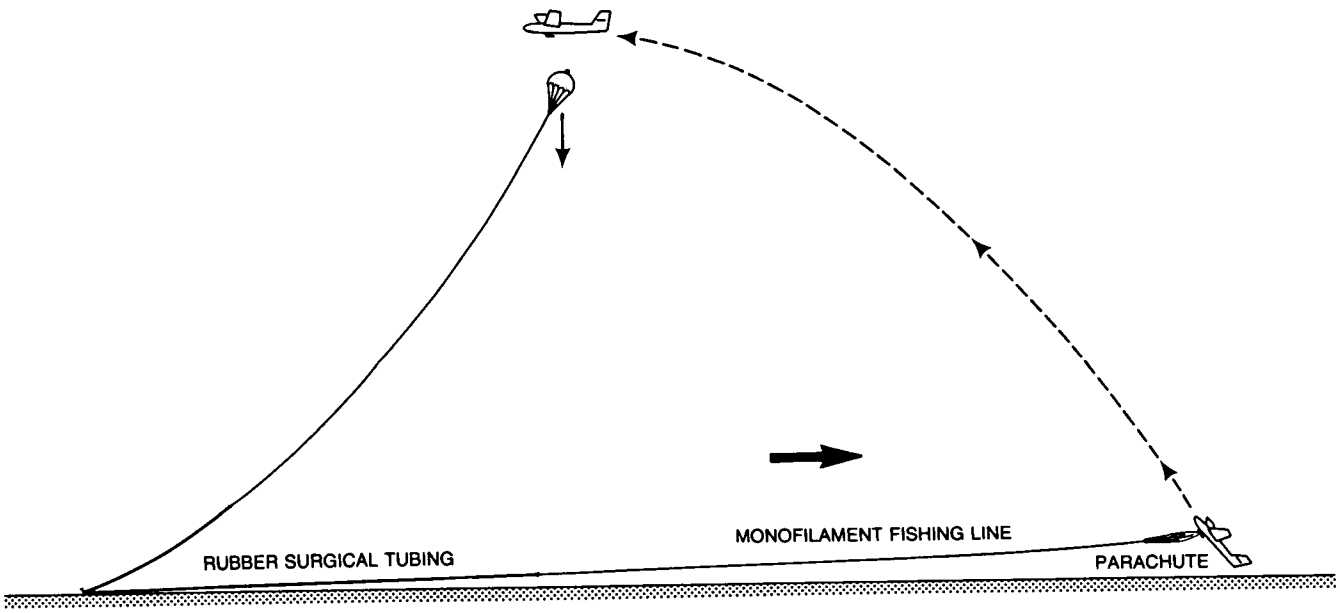


FIGURE 1
HI-START CONFIGURATION

All of the components for assembly of the hi-start are available in even the smaller cities, if the flier wants to assemble his own. The problem revolves around the cost of the surgical tubing. I suspect that most surgical supply houses where Joe Flier would have to go to get the tubing are used to selling to hospitals at inflated prices, and you can't get there from here. A call to two surgical supply houses got quotes of $50.00 and $60.00 for 100' of tubing. A quick check of discount prices told me I could get the whole complete hi-start for around $40.00, and just the tubing for $20.00. Anyway — you can make the parachute and the fishing type components are readily available; the stake is a 10'' spike or tent stake or screwdriver.

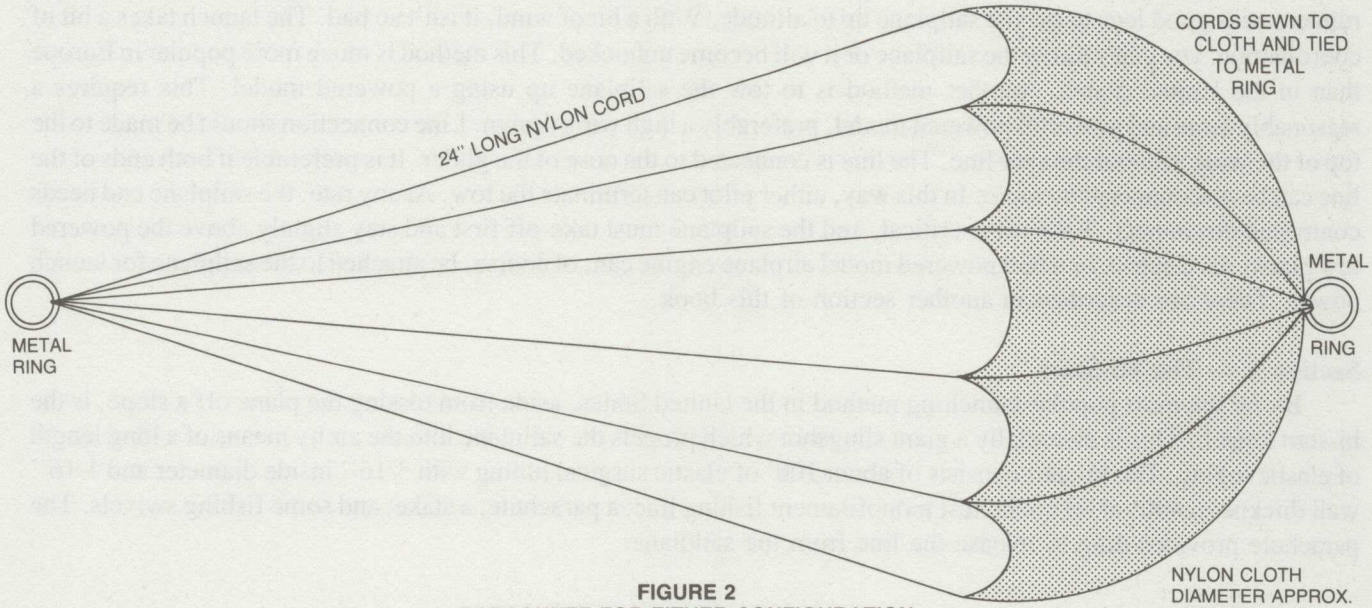
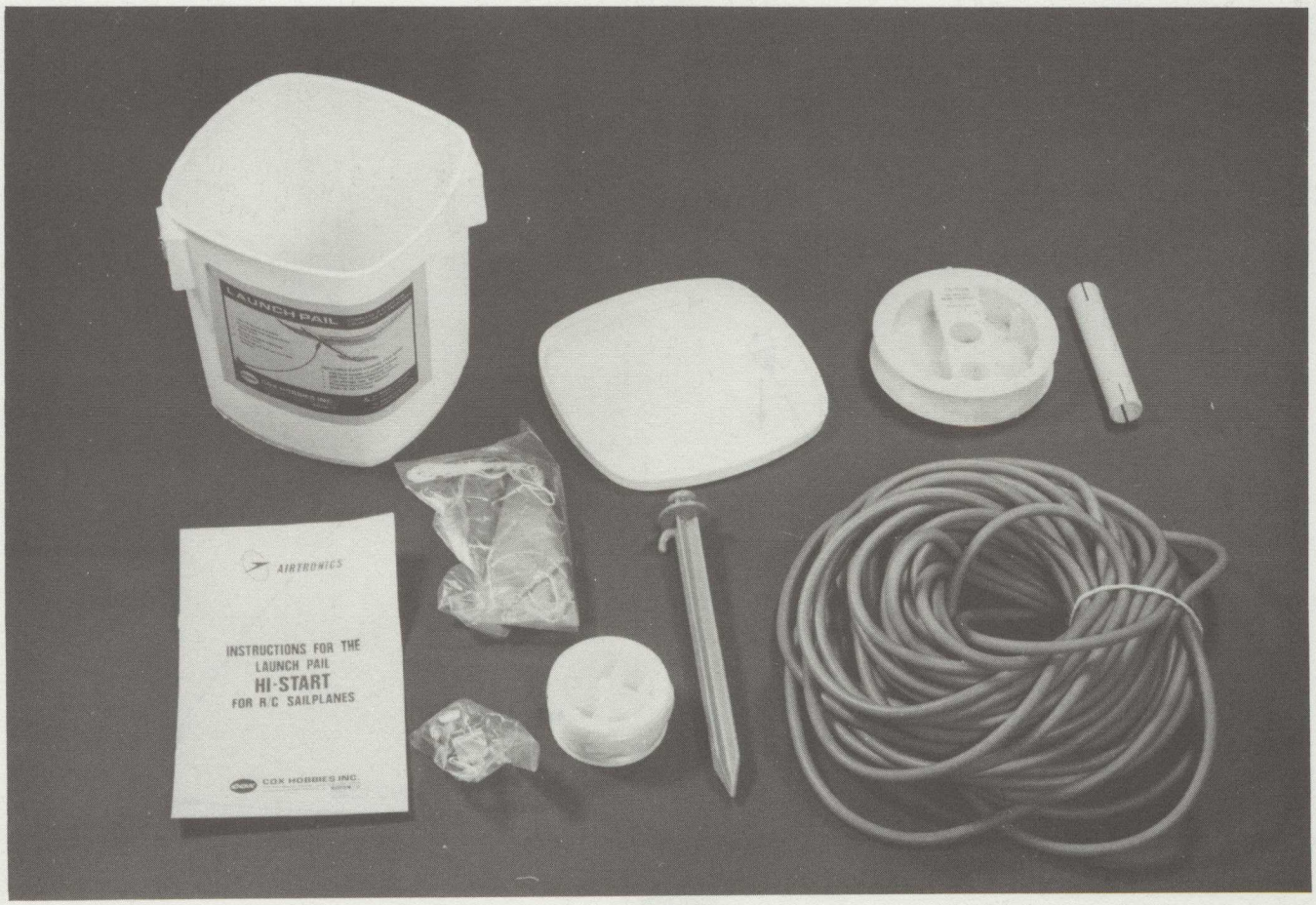


FIGURE 2
PARACHUTE FOR EITHER CONFIGURATION

You need a reel for the line and a reel for the surgical tubing so unless Uncle Harvey owns a surgical supply house, I guess my recommendation for the day is — buy a hi-start.



Airtronics' commercial hi-start.

I suggest you buy a heavy duty hi-start. It will be zippy for your beginning gliders but if you keep it out of the sunlight when not in use and dry it off before putting it away (dusting with talcum powder), it should last for three to five years.

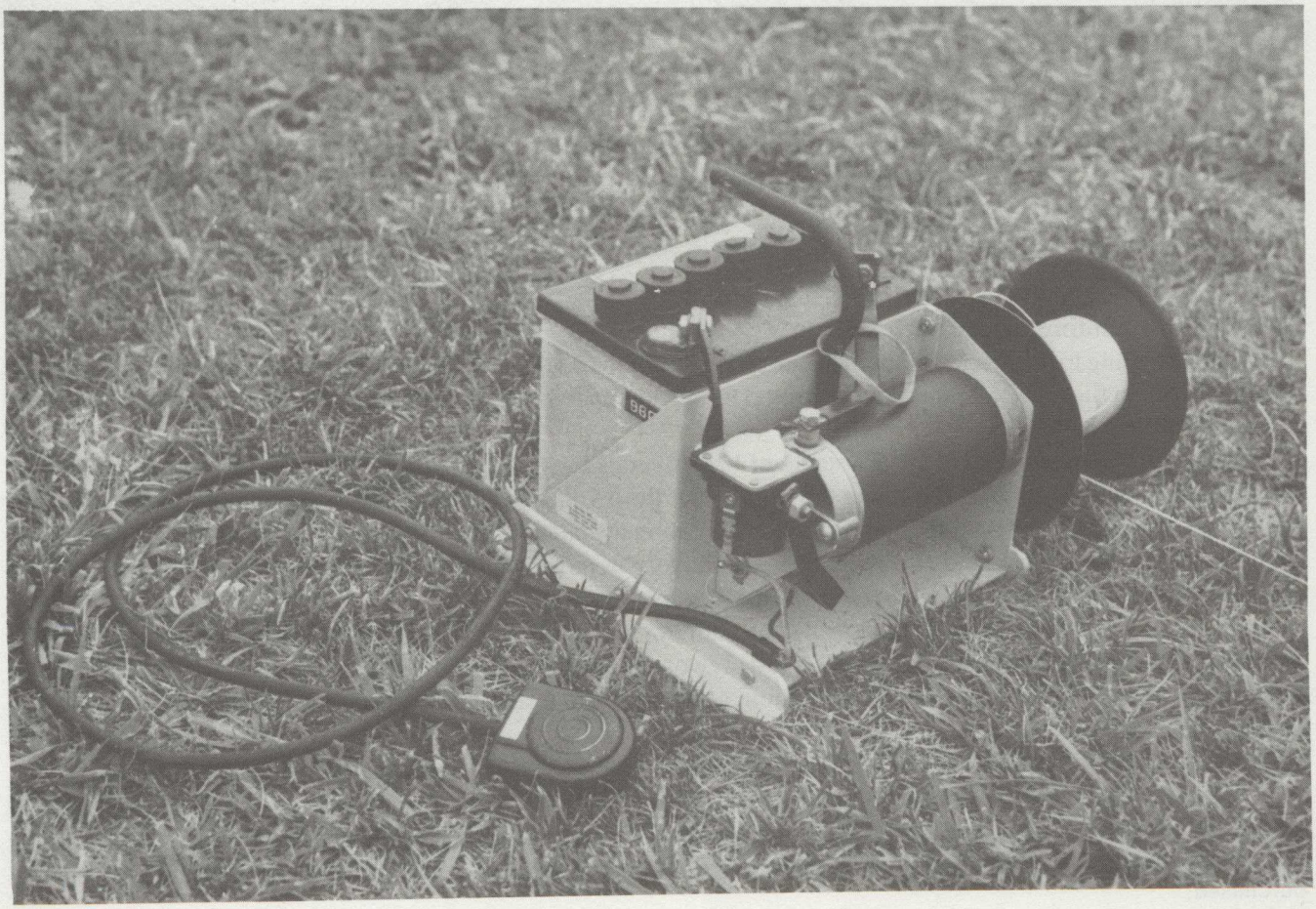
Section 2 — Electric Winches

Electric winches have two advantages over the hi-start; they are much more powerful and, once set up, are more convenient to use.

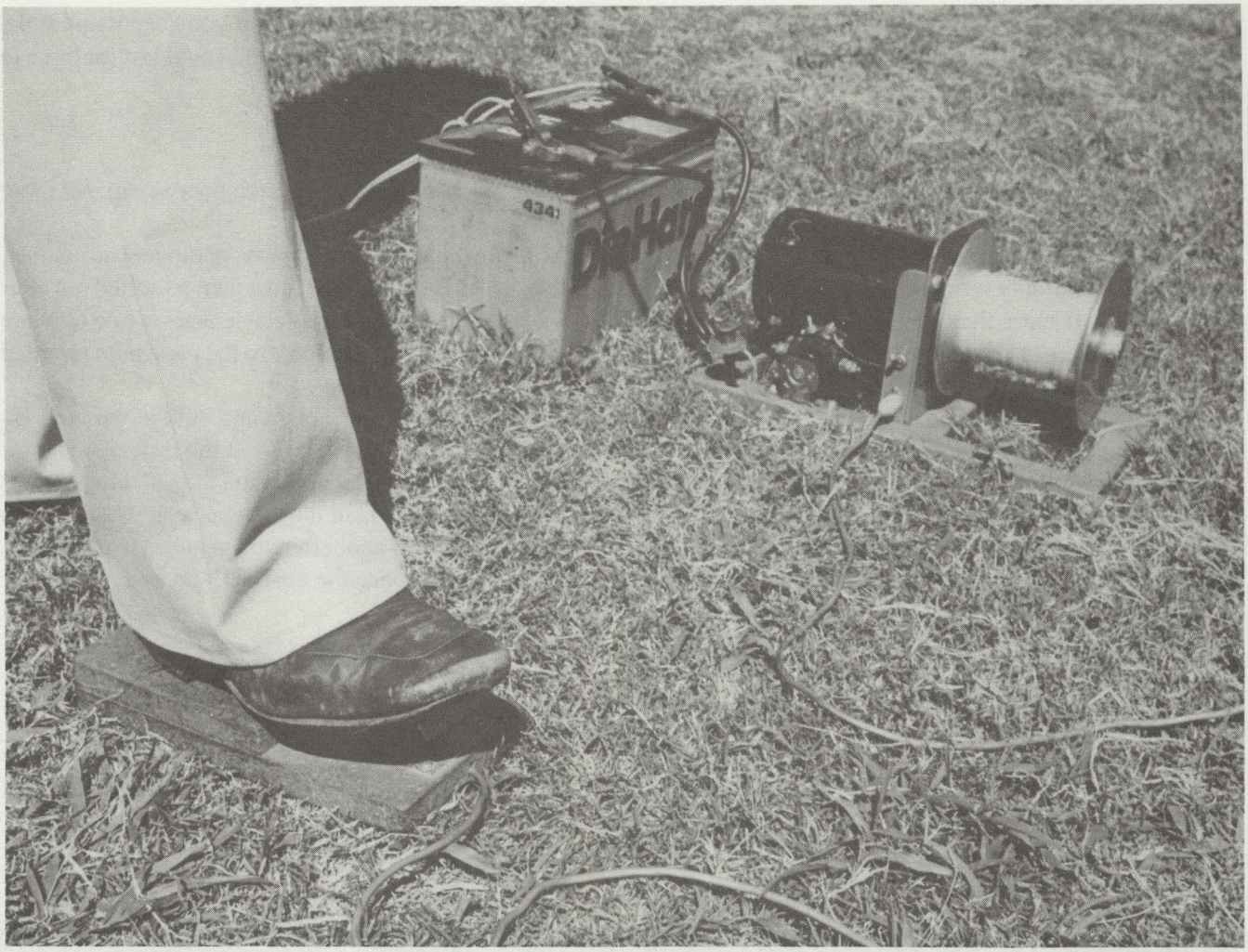
One big problem with the hi-start is that if you fly on a field with any kind of brush, weeds, or other obstructions, the line will invariably be blown to one side or the other and get tangled in the bushes. It must then be sorted out after every launch. If more than one hi-start is set up, one will blow across the other and a delay ensues while they are uncrossed. After each launch, the electric winch is run down, either by the flier or a helper, so the parachute is pulled near the turn-around. The line may then be pulled straight back to the launch area.

Disadvantages of the electric winch are: initial cost, maintenance cost and the weight and bulk of the unit. By the time you buy the battery and line, a commercially built winch will cost about $250.00, at the time of writing.

Batteries must be recharged with each use and replaced every three or four years. And the darned thing weighs about 75 pounds. Getting it in and out of the car is a grunt and if you have far to haul it once you're at the field, you need a dolly. But — they are indispensable for getting large sailplanes in the air and, after you get used to using one, are easier to use than a hi-start. If a group, such as a club, buys or builds one, the cost isn't so bad.



Fab Tec commercial winch.



Mark's Models electric winch.

Section 3 — Building An Electric Winch

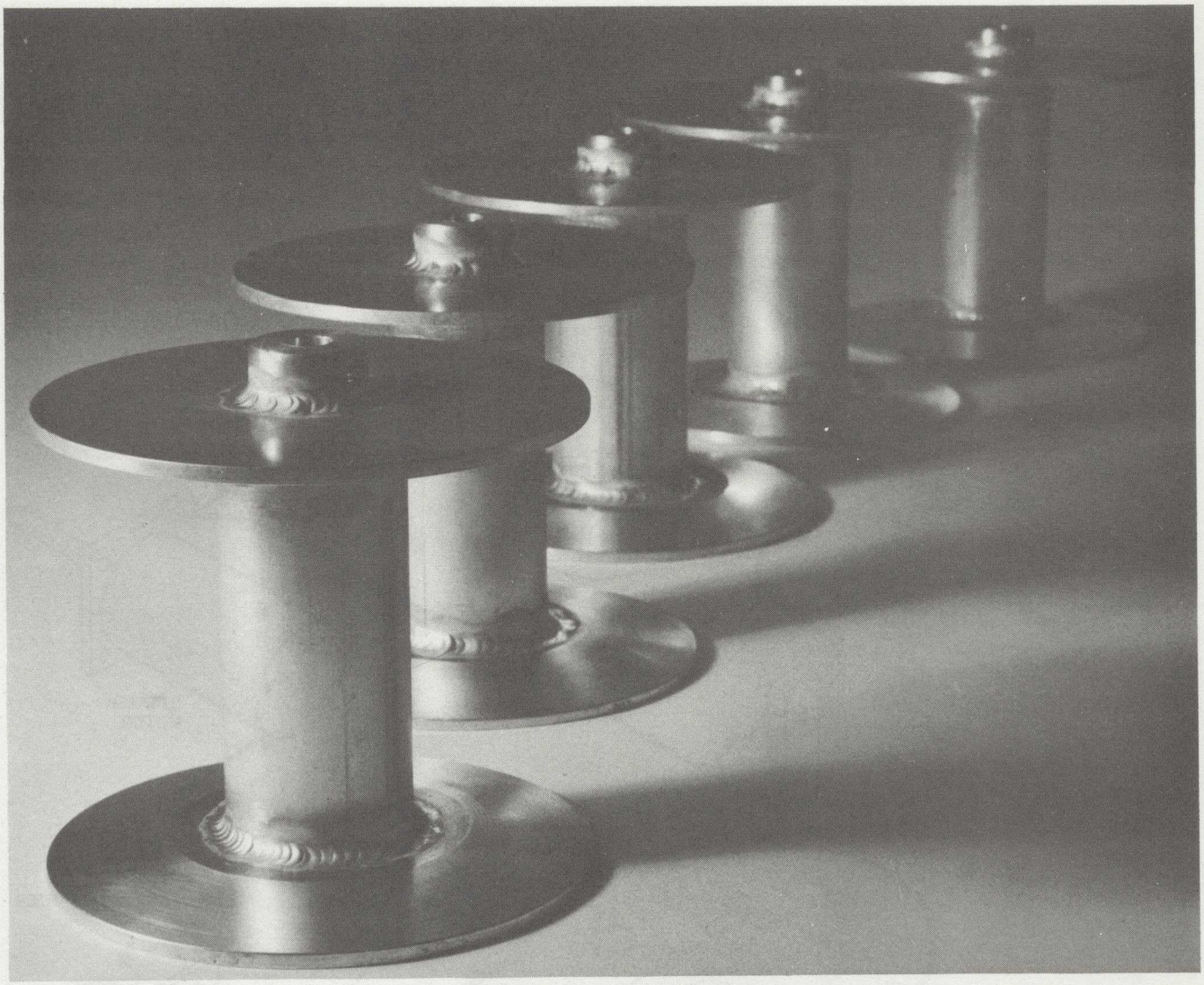
The first thing to decide is whether you are going to build a 6 volt or 12 volt winch. The 12 volt winch is popular among advanced fliers because it is really peppy. During downwind launch conditions, the 12 volter will still do a job of hauling the sailplane up.

It has a further advantage of using a standard 12 volt car battery which is more obtainable than the 6 volt battery. I believe, however, that most winches in the U.S. are of the 6 volt type. Perhaps this is because this is the way they started out and people got used to them. From an operational standpoint, I would recommend starting with a 6 volt one. They are a bit more gentle and more than satisfactory in most launch conditions. A 12 volt winch can be too much for a beginning, or somewhat inexperienced, pilot to handle.

The winch described here was designed to be built by the average guy who is handy with tools, but requires only those tools you are likely to have. It is housed in a plywood box which is heavier than the open welded frame used by commercial winches but does not require welding equipment and is also a neat place to store the turn-around, foot switch, etc.

An alternative construction method may be found in the June 1976 issue of R/C Modeler Magazine.

From a procurement standpoint, the most critical item is the drum. Unless you are very well-equipped and a very good mechanic, I suggest you buy this item. It requires a very sturdy hub as the crushing force of the wrapping line is incredible. For a 6 volt winch, a 4'' hub is used and for 12 volts, a 2'' hub. Hub size must be specified when purchased.



Winch drums available from Mark's Models, 1578 Osage, San Marcos, Calif. 92069.

The motor is a Ford starter motor and normally runs from 12 volts. Some of the speed lost when running it on 6 volts is made up by the larger 4'' hub diameter, but it does run slower than if 12 volts were used. In any event, the same motor is used on either version. This motor was selected because it has a long shaft on which to mount the drum. The starter was used in Fords for a long time and is a common item in auto wrecking yards. Just ask for a long shaft starter, motor vintage 1964. The shaft is 5¾'' long. They can be had for about $10.00. Normally, at wrecking yards, what you see is what you get, so it's wise to have a knowledgeable person select a starter with good bearings and brushes, one that turns freely with no end or side play to the shaft (not the one the salesman is going to give you — the one in the starter). If possible, get out your jumper cables and try it before you buy. Or, for a bit more money, you can get a rebuilt motor from an auto parts house.

Placement of the various components is not critical. Locations are shown in Figures 3 and 4.

The motor is mounted about 6'' from the top, and 6'' from the front, on the left hand side of the box. The motor has a flange that prevents it from setting flat when mounted. The side must, therefore, be routed out or carved with a wood chisel, so the motor will mount solidly.

The brake shown is optional, but handy for stopping the drum. It is nothing more than a piece of 2 x 4 wood, to be pressed against the drum, or swung out of the way.

A 6 volt golf cart battery was used in the author's winch. These are designed for the deep discharge duty seen in winch operation. They also have holes in the terminals for bolt-on cables. These make battery removal easier, which facilitates one-man winch handling.

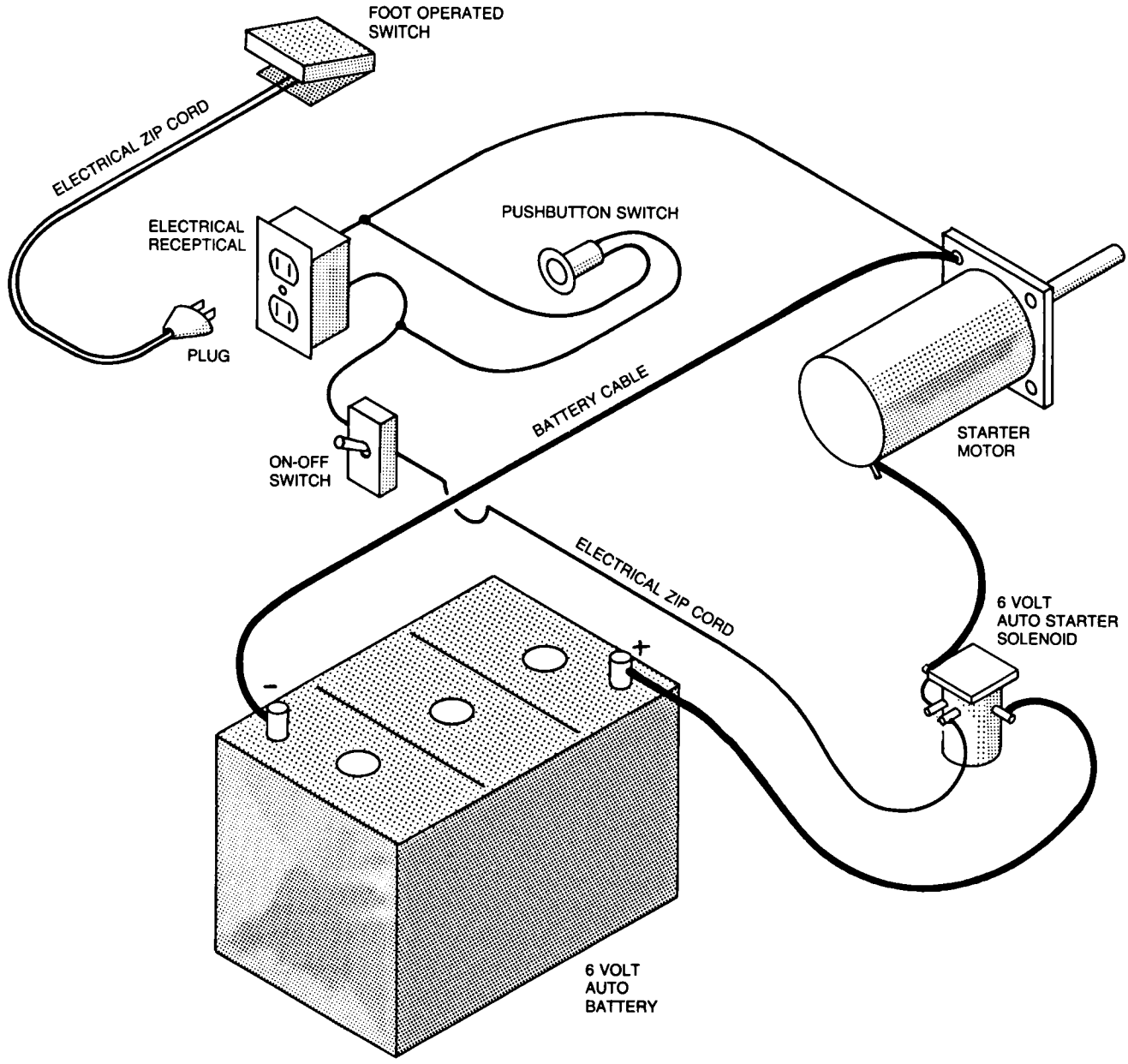


FIGURE 3
SCHEMATIC — ELECTRIC WINCH

BOX (1/2" PLYWOOD)
BOTTOM — 13" x 16" (1)
SIDES — 13" x 17" (2)
ENDS — 13" x 13" (2)
TOP — 17" x 14" (1)

1. STARTER MOTOR 1964 FORD.
2. BATTERY 6 VOLT AUTO.
3. 6 VOLT SOLENOID 4 TERMINAL.
4. 12" BATTERY CABLE (3).
5. ELECTRICAL "ZIP" CORD 6'.
6. DOORBELL SWITCH.
7. ON/OFF SWITCH 115V WALL MOUNT.
8. 115V ELECTRICAL OUTLET.
9. 115V ELECTRICAL PLUG.
10. FOOT SWITCH — RADIO SHACK.
11. 6" x 12" x 1/2" PLYWOOD.
12. DRUM — 4" HUB — MARK'S MODELS.
13. BOLT & NUT 1/4" x 1¼" ALLEN HEAD.
14. CUP HOOK.
15. HANDLES (2).
16. 1/4" IRON ROD — 2'.
17. U-BOLTS (2).
18. 3/16" x 1½" BOLTS & NUTS (8).
19. 2" x 4" PINE 5" LONG.
20. 3/4" x 1/8" IRON STRAP — 2'.
21. WOOD SCREWS (6).
22. 1/2" BOLT 6" LONG.
23. 1/2" NUTS (3).
24. FRONT BICYCLE HUB WITH NUTS.
25. 1" U-BOLT 3" LONG (2).
26. 5¼" x 8" x 1/2" PLYWOOD.
27. 1½" x 8" x 1/2" PLYWOOD.
28. 6" SPIKE.
29. HINGES (2).
30. 1800' OF 120 LB. TEST NYLON CORD.

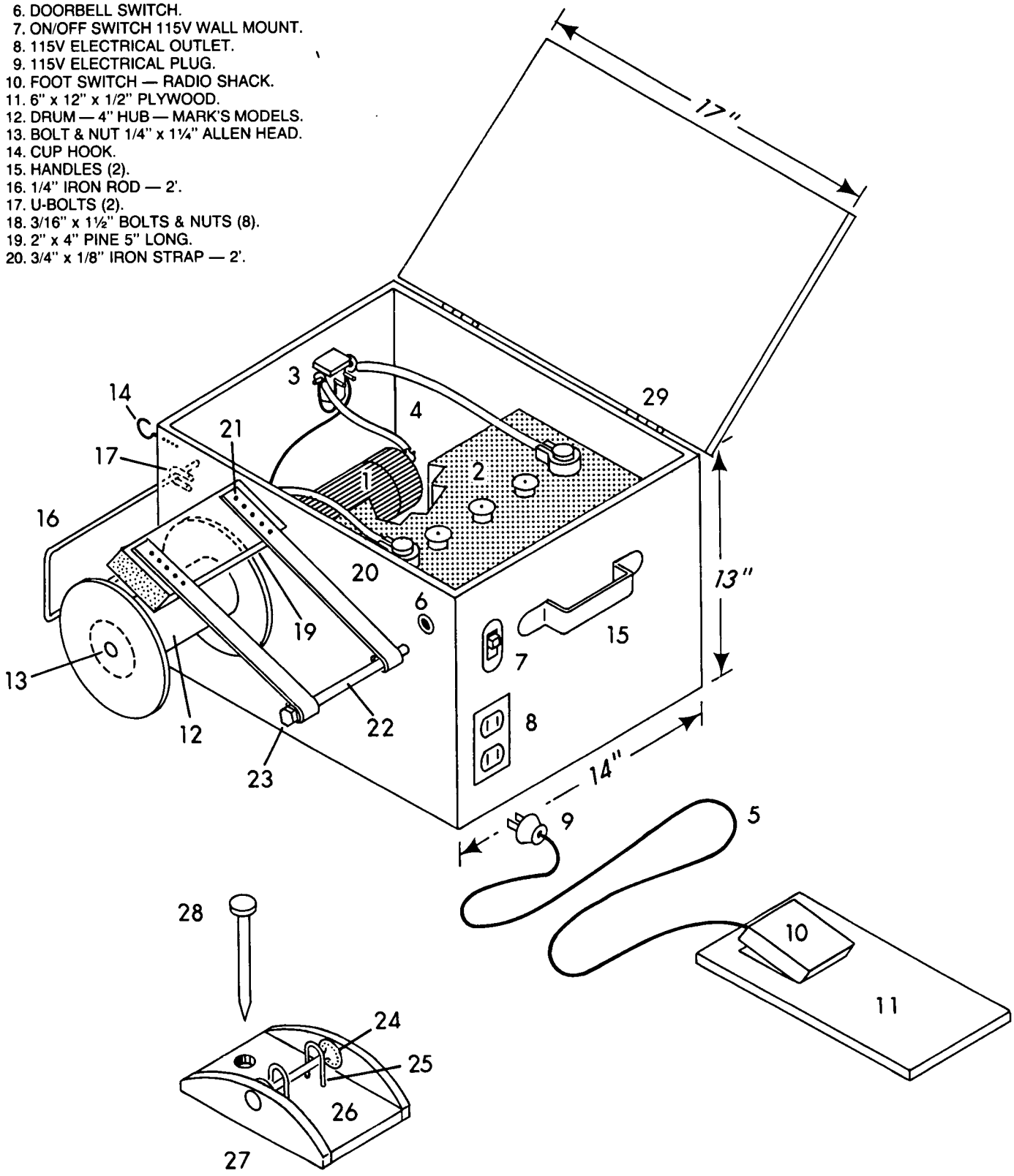


FIGURE 4
ELECTRIC WINCH CONSTRUCTION